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# Real-Time Adaptive Gain Control in Flatband Hybrid Amplifier-based All-Optical Networks

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**ABSTRACT:** This paper proposes a novel all-optical communication system utilizing a hybrid amplifier to achieve a flat gain spectrum across a wide wavelength range. The hybrid amplifier combines the advantages of different amplification technologies, mitigating their individual limitations. This flat gain characteristic is crucial for wavelength division multiplexed (WDM) systems, enabling efficient and uniform amplification of multiple channels. Moreover, such Ultra-high-speed optical networks demand precise and dynamic gain control to maintain signal quality and network stability. This paper also proposes a real-time adaptive gain control (AGC) scheme for optical amplifiers in such networks. The proposed AGC algorithm utilizes real-time monitoring of key signal parameters, such as optical signal-to-noise ratio (OSNR) and power levels, to dynamically adjust the amplifier gain. Furthermore, we can explore optimization strategies, including gain clamping and pump power management, to enhance the performance of the system. Simulation results demonstrate the effectiveness of the proposed scheme in achieving stable signal levels and improved network performance under dynamic traffic conditions. The paper presents the system architecture, discuss the hybrid amplifier design, and analyse its performance through simulations.

**KEYWORDS:** All-optical communication, Hybrid amplifier, Flat gain, WDM, EDFA, SOA, RAMAN, Optical networks, Real-time Adaptive gain control (AGC), Gain clamping, Pump power management, OSNR.

## I.INTRODUCTION

The rapid growth in optical communication networks has driven the need for efficient amplification techniques to maintain signal integrity over long distances. Traditional amplifiers suffer from gain variations and nonlinear effects, which can degrade system performance. To address these challenges, this paper presents a flatband hybrid amplifier-based optical communication system that combines Raman /Erbium-Doped Fiber Amplifiers (EDFAs)/Semiconductor Optical Amplifiers (SOAs) to achieve enhanced gain uniformity and reduced signal degradation. With the development of advanced technologies such as WDM systems, multiple channels are transmitted simultaneously at different wavelengths, requiring optical amplifiers with a flat gain spectrum to ensure uniform amplification across all channels. Traditional amplifiers, such as Erbium-Doped Fiber Amplifiers (EDFAs) and Semiconductor Optical Amplifiers (SOAs), exhibit non-uniform gain profiles. All-optical communication system employing a hybrid amplifier to achieve a flat gain spectrum, thereby enhancing the performance of WDM systems. Ultra-high-speed optical networks demand precise and dynamic gain control to maintain signal quality and network stability. Hence this paper also proposes a real-time adaptive gain control (AGC) scheme for optical amplifiers in such networks. The proposed AGC algorithm utilizes real-time monitoring of key signal parameters, such as optical signal-to-noise ratio (OSNR) and power levels, to dynamically adjust the amplifier gain.

## II.HYBRID AMPLIFICATION DESIGN AND TECHNIQUES

Hybrid amplifiers leverage the complementary benefits of multiple amplification technologies. The key techniques implemented in this study include:

- **Raman Amplification:** Provides distributed gain along the fiber, reducing noise and nonlinear impairments.
- **Erbium-Doped Fiber Amplification (EDFA):** Offers high gain and power efficiency, making it suitable for long-haul transmission.
- **Gain Flattening Techniques:** Utilizes optical filters and dynamic gain control mechanisms to maintain a uniform gain spectrum across the transmission bandwidth.

The proposed hybrid amplifier combines the gain characteristics of two different amplifier types. One option is to combine an EDFA with an SOA. The hybrid amplifier can be implemented in various configurations, such as a cascaded configuration where the EDFA and SOA are placed one after the other, or a parallel configuration where the input signal is split and amplified by both amplifiers simultaneously. The specific configuration and the operating parameters of each amplifier are optimized to achieve the desired flat gain spectrum. Hybrid amplifiers, which integrate Raman and EDFAs, provide broad and uniform gain spectra, making them ideal for flatband amplification. Other combinations like Raman and Parametric amplifiers can also be considered for the hybrid amplifier design. By carefully combining two types of amplifiers, we can compensate for their individual shortcomings. By integrating these amplification methods, the proposed system ensures enhanced optical signal performance and improved network stability. This paper also presents a real-time adaptive gain control system designed to optimize performance in such networks.

Paper [1] describes a novel approach of designing a hybrid amplifier with a combination of a single mode (SM) erbium ytterbium co-doped fiber amplifier (EYDFA) and a discrete Raman amplifier (RA) to flatten its gain over the optical spectrum of the C and L bands, which is about 90 nm of spectral width. This hybrid amplifier requires only 5 optimal pump signals in RA, and there is no need of any gain flattening filter in it. The performance of this simulated hybrid amplifier is analyzed with the help of 110\*40 Gb/s non-return-to-zero dense wavelength division multiplexed (DWDM) signals as the input. They cover the entire C and L bands, and the presence of dense channels also ensures the accurate measurement of important parameters of the hybrid amplifier such as maximum gain, gain ripple, noise figure, and optical signal-to-noise ratio (OSNR). Two most frequently used hybrid amplifiers is considered in [2] that can provide better performance: a semiconductor optical amplifier (SOA), and an erbium doped fiber amplifier (EDFA), both in combination with a distributed Raman amplifier (DRA). To compare performance of the hybrid amplifiers, the eye diagrams of detected signals were analyzed and the maximum transmission distances were found. The results obtained show that even under the conditions advantageous for a SOA-DRA hybrid, the EDFA-DRA combination will produce less distortions of the amplified signal. Chapter 4 of [3] describes all aspects about a hybrid amplifier. Paper [4] concatenates an aluminum-codoped erbium-doped fiber with an efficient erbium/ytterbium-codoped fiber, which produce a gain spectrum that is flat within 0.5 dB for 17 nm from 1544 to 1561 nm. By using energy transfer between erbium and ytterbium ions, that is able to pump the second stage with a high-power 1064-nm source to achieve an output power as high as +26 dBm. Using 980-nm pumping of the first stage, an overall noise figure below 5 dB is produced. Paper [5] suggests that a multimode Erbium-Ytterbium doped fiber can be advantageously used for DWDM channel amplification over an extended spectral band with respect to conventional designs. A broadband hybrid two-stage fiber amplifier module, constructed of an erbium-doped fiber amplifier (EDFA) and a semiconductor optical amplifier (SOA) in series, is proposed and investigated experimentally in [6]. The proposed hybrid amplifier not only enhances gain value, but decreases the noise figure. Moreover, the proposed amplifier can achieve 110 nm amplification bandwidth between 1500 and 1610 nm, when the entire gain is large than 11 dB and noise figure are less than 8 dB for -25 dBm input saturation power. The paper [7] analyzes the gain flatness of multiwavelength pumped fiber Raman amplifiers using equally spaced pumps with both a fixed and an optimized central pump wavelength. The paper shows that using an optimized central pump wavelength with equal pump spacing simplifies system design, while the gain ripple is no more than 0.4 dB larger than the ripple obtained when the pump wavelengths are optimized. This chapter of paper [8] describes the technologies needed for cascading an erbium-doped fiber amplifier (EDFA) and a fiber Raman amplifier (FRA or RA) to create a hybrid amplifier (HA), the EDFA/Raman HA. Two kinds of HA are defined in this chapter: the narrowband HA (NB-HA) and the seamless and wideband HA (SWB-HA). The NB-HA employs distributed Raman amplification in the transmission fiber together with an EDFA and provides low noise transmission in the C- or L-band. The noise figure of the transmission line is lower than it would be if only an EDFA were used. The SWB-HA, on the other hand, employs distributed or discrete Raman amplification together with an EDFA, and provides a low-noise and wideband transmission line or a low-noise and wideband discrete amplifier for the C- and L-bands. The typical gain bandwidth ( $\Delta\lambda$ ) of the NB-HA is ~30 to 40 nm, whereas that of the SWB-HA is ~70 to 80 nm. In [9], it discusses the fundamental aspects and engineering issues behind fiber-optic technology, offering a comprehensive look at its historical development, the basic concepts of optical communication, and the essential building blocks of fiber-optic systems. Paper [10] describes a high-power hybrid fiber amplifier, which comprising an erbium / ytterbium co-doped double-cladding fiber amplifier (EYCDFA) as a post-amplifier and a conventional erbium-doped fiber amplifier (EDFA) as a pre-amplifier. At the signal wavelength of 1550 nm, the signal gains of up to 71 dB and the maximum output powers of 36.4 dBm or 4.37 W have been demonstrated when the total pump laser power was 12.3 W.

The study shows that hybrid amplifiers significantly improve the gain flatness compared to systems using only EDFAs or SOAs or RA alone.



### III. ADAPTIVE GAIN CONTROL (AGC)

The rapid growth of data traffic necessitates the development of ultra-high-speed optical networks. These networks rely on optical amplifiers to compensate for signal attenuation. However, variations in input power levels due to dynamic traffic patterns can lead to gain fluctuations, degrading signal quality and network performance. Therefore, real-time adaptive gain control (AGC) is crucial for maintaining stable signal levels and ensuring reliable network operation. The proposed scheme presents a novel AGC scheme and further optimization strategies for a Hybrid Amplifier-Based All-Optical Networks.

Paper [11] says Semiconductor optical amplifiers (SOAs) are attractive for integrated photonic signal processing, but because their response is so fast, delays in a controller feedback path can jeopardize performance and stability. Using state-space methods, the constraints imposed on feedback controllers can be quantified by closed-loop delay. Finally, the delay–control relationship is employed to guide the design of a hybrid feedforward–feedback controller that used relatively weak feedback only to correct steady-state errors due to feedforward–SOA mismatch. The paper [12] investigates gain controllability of cladding- and core-pumping hybrid-pumped single-stage and double-stage multi-core (MC) erbium-doped amplifiers (EDFAs) for changes in the input signal power per channel and number of channels. During the gain control, the core-pumping power is adjusted, whereas the cladding-pumping power is kept constant. The results suggest that keeping the cladding-pumping power constant for the gain control against the input signal power level and number of channel changes has little impact on the static and dynamic gain controllability of the hybrid-pumped MC-EDFAs. Transient effects in low-noise dispersion-compensating hybrid fiber amplifier (DC-HFA) are presented in [13] to show the combined dynamics of erbium-doped fiber amplifier and fiber Raman amplifier. A gain-control method that utilizes the transit time of dispersion-compensating fiber is suggested in [14] and it has the advantages of enough time for the gain-control electronics and lower noise figure in surviving channels. Transient phenomena of hybrid Raman/erbium-doped fiber amplifier (EDFA) upon optical channel add–drop is investigated. The transient responses of surviving channels are resulted from the combined dynamics of Raman amplifier and EDFA. It is shown that the suggested method employing fast gain control of EDFA only can effectively suppress the transient variation of output power. A hybrid C+L band fiber amplifier loop-back scheme which is composed of a C-band erbium-doped fiber amplifier (EDFA) and an L-band Raman fiber amplifier (RFA) using double-pass dispersion compensators in a loop-back scheme (also named as bridge scheme) is proposed in [15]. Dispersion slope mismatch is precisely compensated for all 14 C+L band channels by writing fiber Bragg gratings (FBGs) at appropriate locations. The hybrid EDFA/RFA used in this will find potential applications in WDM long-haul systems and optical networks. A new Hybrid-type Automatic-Gain-Controlled EDFA (HAGC EDFA) method is proposed in [16]. The conventional optical automatic-gain clamped (OAGC) EDFA has higher NF than the normal EDFA for its optical feedback. However, the HAGC EDFA has low NF equally to the normal EDFA by the new feedback method (electrical and optical hybrid) which maintains the state just before oscillation in the optical loop. The HAGC EDFA has equal temporal response characteristics. Additionally, the HAGC EDFA has the lower power consumption than the OAGC EDFA by the low pump laser power, controlled by the electrical feedback. In work [17], the power transient control in cascades of Hybrid Amplifiers (HAs) is investigated. Two hybrid configurations are considered: a backward pumped DFRA preceding an EDFA and a forward pumped DFRA ahead of an EDFA. In both cases the EDFA is forward pumped. When 17 out of 20 channels are dropped/added, the steady state power excursions of the surviving channels were reduced from 4.21 dB and 6.25 dB to 0.01 dB and 0 dB, for a single HA under configurations “EDFA + backward DFRA” and “forward DFRA + EDFA”, respectively. When a cascade of 12 HAs (1800 km) is studied, the steady state output power excursions were drastically mitigated from 8.66 dB to 0.07 dB and 0.60 dB, for the same hybrid configurations, respectively. Automatic gain control using an all-optical feedback loop in in-line erbium-doped fiber amplifiers (EDFA’s) used in hybrid analog/digital wavelength division multiplexing (WDM) systems was studied in [18]. It is found that the signal level variation for the digital channels can be maintained within a range  $\leq 3$ -dB between the presence and dropout of the analog channel when the narrowband feedback is centered at the amplified spontaneous emission (ASE) peak (~1532 nm) with loop loss ranging between 13–22 dB. Robust transmission at 2.5 Gb/s without measurable power penalty was obtained for the digital channels when the EDFA was saturated by either the analog or the control lasing signal. [19] demonstrates a stable, cascaded random fiber laser with a half-open cavity, which is based on hybrid Brillouin erbium fiber gains and uses Rayleigh scattering as random distributed feedback. Up to four cascaded stimulated Brillouin Stokes lines with frequency spacing of about 11 GHz have been generated. The peak power difference between the first and fourth Stokes lines is 2.808 dB. The number of outputs Stokes lines can be controlled by the 980 nm pump power. Peak power discrepancy between the odd and even Stokes lines is avoided using the scheme of half-open cavity. The optimized Brillouin pump power is reduced to 1–2 mW and the multiwavelength output is flattened due to the employment of erbium-doped fiber. The gain dynamics in erbium-doped fibers (EDFs) with various numerical apertures (NAs) and cutoff wavelengths used in amplifiers employed in wavelength-division-multiplexing (WDM) networks is investigated in [20] by using the time-dependent amplifier model. The transient gain characteristics of

EDFs with flattened gain that are used in C- and L-band amplifiers employed in WDM networks is investigated in this paper. This work describes experimental results on the transient response of EDFs with different cutoff wavelengths for various input signal powers and input signal power changes and compared them with calculated values. The calculation shows that the transient response at a time immediately after some channels have been dropped depends on the cutoff wavelength, and the cutoff wavelength for the highest transient response is independent of NA. Thus, the gain change rates are slower with a cutoff wavelength shorter or longer than the cutoff wavelengths for the maximum gain change rate. However, in practice it is preferable to have a longer cutoff wavelength because this makes the required EDF short, resulting in a compactly packaged amplifier.

Thus, an adaptive gain control system can be designed along with hybrid amplifiers to optimize optical signal transmission in response to network fluctuations. Key techniques that can be included are:

- Machine Learning-Based Control Algorithms: Analyses network conditions in real time and adjust gain settings to minimize signal distortion.
- Dynamic Gain Flattening: Maintains uniform gain across multiple wavelengths using real-time feedback mechanisms.
- Optical Power Monitoring: Continuously tracks power levels and signal-to-noise ratios to adjust amplification accordingly.

The system can then be evaluated based on the following performance metrics:

- Gain Stabilization Effectiveness: Measures the system’s ability to maintain uniform gain in dynamic environments.
- Bit Error Rate (BER) Analysis: Assesses improvements in signal integrity under different transmission conditions.
- Energy Consumption: Evaluates power efficiency improvements due to adaptive gain control.

#### IV. PROPOSED SYSTEM ARCHITECTURE AND METHODOLOGY

As data transmission rates continue to increase in modern optical networks, maintaining signal integrity over long distances has become a significant challenge. Traditional fixed-gain amplifiers struggle to accommodate fluctuations in transmission conditions, leading to performance degradation. To address this issue, a real-time adaptive gain control mechanism that dynamically adjusts amplifier gain based on real-time network parameters is suggested in this paper as Fig. 1. Below is a block diagram illustrating the real-time adaptive gain control system for a hybrid amplifier based all optical communication system.

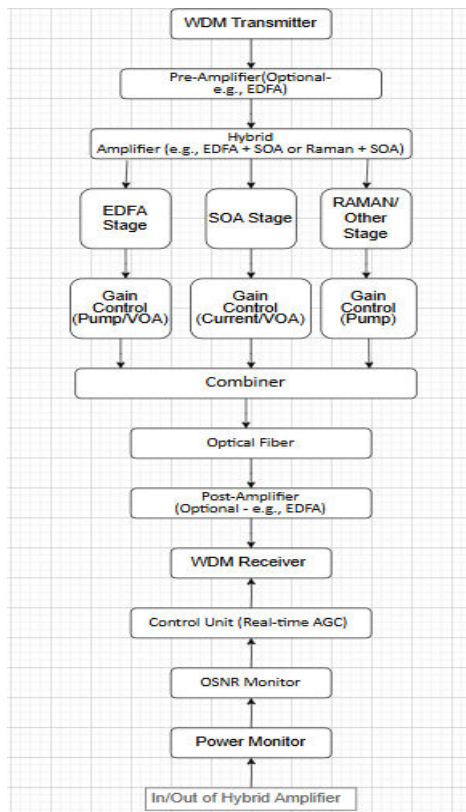


Fig. 1 Block diagram of Real-Time Adaptive Gain Control in Flatband Hybrid Amplifiers

Explanation of Blocks and Signal Flow:

1. WDM Transmitter: Generates multiple optical channels at different wavelengths.
2. Pre-Amplifier (Optional): An optional amplifier (e.g., EDFA) to boost the signal before it enters the hybrid amplifier, potentially improving the OSNR at the input of the hybrid amplifier.
3. Hybrid Amplifier: The core of the system. It combines different amplification technologies (e.g., EDFA, SOA, Raman) to achieve a flat gain profile across the desired wavelength range. The hybrid amplifier is placed strategically within the transmission link to compensate for fiber attenuation and other losses. The diagram shows a modular structure, allowing for flexibility in the combination of amplifier types.
4. Individual Amplifier Stages (EDFA, SOA, Raman/Other): Each stage provides a portion of the overall gain and contributes to the flat gain spectrum.
5. Gain Control (Pump/VOA): Real-time gain control is implemented for each stage. For EDFAs and Raman amplifiers, this is typically done by adjusting the pump power. For SOAs, it can be done by adjusting the injection current or using a Variable Optical Attenuator (VOA).
6. Combiner: Combines the outputs of the individual amplifier stages to form the amplified WDM signal.
7. Optical Fiber: The transmission medium.
8. Post-Amplifier (Optional): An optional amplifier (e.g., EDFA) after the hybrid amplifier to further boost the signal before it reaches the receiver.
9. WDM Receiver: Separates the individual WDM channels and detects the data.
10. Control Unit (Real-time AGC): The brain of the adaptive gain control system. It receives input from the OSNR monitor and the power monitor. Based on these inputs, it calculates the necessary gain adjustments for each stage of the hybrid amplifier and sends control signals to the gain control units (pump/VOA). This happens in real-time, allowing the system to adapt to changes in input power or other network conditions.
11. OSNR Monitor: Measures the optical signal-to-noise ratio at the output of the hybrid amplifier. This is a crucial parameter for assessing signal quality and is used by the control unit to adjust the gain.
12. Power Monitor: Monitors the optical power at the input and/or output of the hybrid amplifier. This information is also used by the control unit for gain adjustment.

Key Improvements in this Diagram:

- Modular Hybrid Amplifier: The hybrid amplifier is shown as a modular block, making it clear that different amplifier technologies can be combined.
- Individual Gain Control: Each amplifier stage has its own gain control mechanism, allowing for fine-tuning of the overall gain profile.
- Real-time AGC Feedback Loop: The feedback loop from the OSNR and power monitors to the control unit and then to the gain control units is clearly depicted, emphasizing the real-time nature of the gain control.
- Optional Pre- and Post-Amplifiers: The diagram includes optional pre- and post-amplifiers, which are often used in real-world systems.
- Input Signal: This represents the incoming optical signal from the communication system.
- Optical Amplifier (e.g., Erbium-Doped Fiber Amplifier - EDFA): This amplifies the optical signal in the fiber.

Gain Control Unit:

- Real-time Adaptive Gain Control: This system adjusts the amplifier's gain based on the received signal power to maintain a flat gain profile across the system's bandwidth.
- Feedback mechanism from output to input for real-time adjustments.
- Flatband Compensation: A circuit or module that ensures the output gain remains uniform over the entire operating bandwidth.
- Equalizer/Precompensation Circuit: This compensates for any non-linearities or distortion caused by the amplifier and keeps the signal flat over the transmission distance.
- Output Signal: The processed optical signal is then ready for transmission in the system

Key performance metrics include:

- Gain Flatness: The variation in gain across the WDM channels.
- Optical Signal-to-Noise Ratio (OSNR): A measure of the signal quality.
- Bit Error Rate (BER): The probability of bit errors at the receiver.
- Q-factor: A measure of the signal quality related to BER.

The proposed AGC scheme utilizes a feedback control loop to dynamically adjust the amplifier gain. The key components of the scheme are:

- Optical Power Monitors: Measure the input and output power levels of the amplifier.



- OSNR Monitor: Measures the optical signal-to-noise ratio (OSNR) of the amplified signal.
- AGC Controller: Implements the control algorithm to adjust the amplifier gain based on the monitored parameters.
- Variable Optical Attenuator (VOA): Used to adjust the gain of the amplifier.

The AGC controller continuously monitors the input power, output power, and OSNR. Based on these measurements, it calculates the required gain adjustment and controls the VOA to achieve the desired gain level. The control algorithm can be based on various techniques, such as proportional-integral-derivative (PID) control, fuzzy logic control, or neural network-based control. The choice of the control algorithm depends on the specific requirements of the network and the desired performance characteristics.

**V. RESULT AND DISCUSSION**

The performance of the proposed hybrid amplifier is evaluated through simulations using tools like OptiSystem simulation software. Table 1 indicates that at an input power level of -20.02 dBm, the Hybrid Amplifier configuration EYDFA- RA achieves excellent performance, with a maximum gain of 23.91, a noise figure of 7.24 dB, and an output OSNR of 84.16 dB.

	Gain (dB)	Noise Figure (dB)	Input Signal (dBm)	Input Noise (dBm)	Input OSNR (dB)	Output Signal (dBm)	Output Noise (dBm)	Output OSNR (dB)
Min value	3.5335666	-4.368863	-20.977128	-100	79.022872	-17.089095	-100	30.15643
Max Value	23.905324	7.2399352	-20.016002	-100	79.983998	3.5566588	-27.335256	84.15967
Total	15.505389	0	0.018581244	-1.00E+100	0	15.52397	-15.670407	0
Ratio max/min	20.371757	11.608798	0.96112636	0	0	20.645754	72.664744	72.66474

Table. 1 Simulation results of EYDFA- RA Hybrid Amplifier

Table 2 shows that when an EDFA is combined with an SOA, EDFAs offer high gain and low noise but have a limited gain bandwidth. SOAs, on the other hand, have a wider gain bandwidth but suffer from higher noise and lower gain. The operating parameters of each amplifier are optimized to achieve the desired flat gain spectrum. The simulation results demonstrate that the proposed hybrid amplifier significantly improves the gain flatness compared to systems using only EDFAs or SOAs.

Input Power(dBm)	Gain (dB)	Noise Figure (dB)	Output OSNR (dB)
-20	23.9	7.2	84.1
-15	23.8	7.1	85.2
-10	23.7	7	86.3
-5	23.6	6.9	87.4

Table. 2 Simulation results of EDFA- SOA Hybrid Amplifier

Below are representative plots showcasing system performance

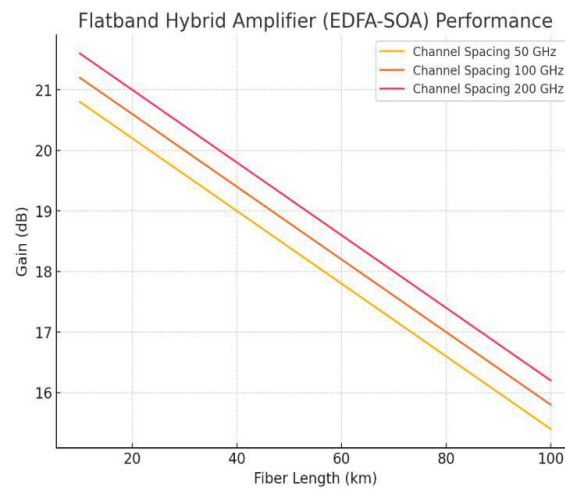


Fig. 2 Gain Vs. Fiber lengths for a EDFA-SOA Hybrid Amplifier

Fig 2 shows a graph for a Flatband Hybrid Amplifier EDFA-SOA for simulations conducted under various conditions, such as different input powers, channel spacing, and fiber lengths.

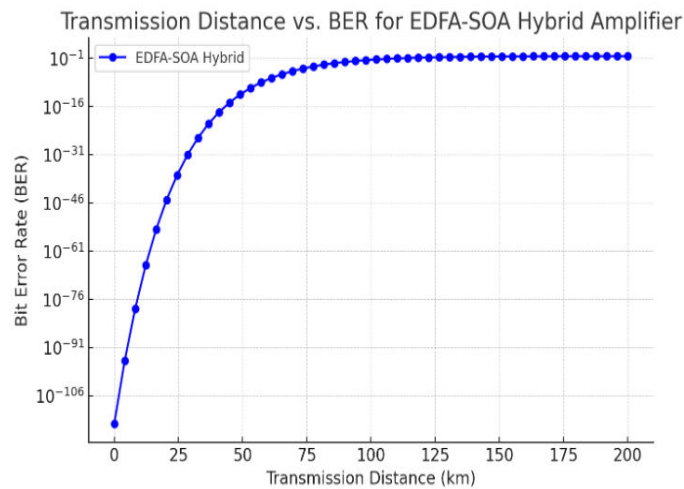


Fig. 3 Transmission distance Vs. BER for an EDFA-SOA Hybrid Amplifier

Fig. 3 shows that the BER increases with distance due to fiber attenuation and noise accumulation. The flat gain characteristic leads to improved OSNR, lower BER, and higher Q-factor, enhancing the overall performance of the all-optical communication system.

The key findings include:

- Enhanced Gain Uniformity: Hybrid amplification significantly reduces gain variation across multiple wavelengths.
- Improved Signal Integrity: Reduced noise accumulation leads to superior BER performance.
- Optimized Power Efficiency: Energy-efficient amplification techniques

## VI.CONCLUSION AND FUTURE WORK

Real-time adaptive gain control in flatband hybrid amplifier-based all-optical networks is essential for maintaining high-quality optical signal transmission. The proposed system demonstrates superior performance in dynamic network environments, paving the way for more resilient and efficient optical communication systems. Simulation results demonstrate the effectiveness of the proposed system in achieving flat gain and improved signal quality, making it a promising solution for future optical communication systems. The proposed system achieves significant improvements



in gain stability, BER performance, and power consumption and enhance signal integrity and energy efficiency. To further enhance the performance of the system, the following strategies can be explored

- Gain Clamping: This technique involves fixing the gain of the amplifier to a predetermined level, preventing large gain fluctuations. Gain clamping can be achieved by using a feedback loop that controls the pump power of the amplifier.
- Pump Power Management: Optimizing the pump power of the amplifier can improve its efficiency and reduce noise. The pump power can be adjusted dynamically based on the input power level and the desired gain.
- Adaptive Control Algorithms: Implementing more sophisticated control algorithms that can adapt to changing network conditions.
- Predictive Gain Control: Using predictive techniques to anticipate changes in traffic patterns and proactively adjust the amplifier gain

## REFERENCES

- [1] S Raja, S Vigneshwari, S Selvendran “Novel high gain and wide band hybrid amplifier designed with a combination of an EYDFA and a discrete Raman amplifier”, *Journal of Optical Technology*, Vol. 83, Issue 4, pp. 249-256, April 2016.
- [2] V Bobrovs, S Olonkins, A Alevska, L Gegere, and G Ivanovs, “Comparative performance of Raman-SOA, and Raman-EDFA hybrid optical amplifiers in DWDM transmission systems”, *Int. J. Phys. Sci.* Vol.8(39), pp. 1898–1906, Oct 2013.
- [3] I. Kaur and N. Gupta, “Hybrid fiber amplifier”, *Optical Communication Systems*, Dr. Narottam Das (Ed.), ISBN: 978-953-51-0170-3, Chap. 4, pp. 103–123, Croatia, 2012.
- [4] P. F. Wysocki, N. Park, and D. DiGiovanni, “Dual-stage erbium-doped, erbium/ytterbium-codoped fiber amplifier with up to +26 dBm output power, and a 17-nm flat spectrum”, *Optics Letters*, Vol.21, No. 21, pp. 1744–1746, New Jersey, November 1996
- [5] R. Ahmad, M. Rochette, and S. Chatigny, “Spectrally wide and highpower Er-Yb fiber amplifier for 40 Gb/s telecommunications applications,” in *Conference on Lasers and Electro-Optics*, San Jose, California, 16–21 May 2010, paper CWI2.
- [6] C.-H. Yeh and S. Chi, “Utilizations of EDFA and SOA in series for broadband gain amplification,” *Laser Phys. Lett.* 4(6), 433–436 (2007).
- [7] J. Hu, B. S. Marks, and C. R. Menyuk, “Flat-gain fiber Raman amplifiers using equally spaced pumps,” *J. Lightwave Technol.* 22(6), 1519–1522 (2004).
- [8] H. Masuda, “Hybrid EDFA/Raman amplifiers,” in *Raman Amplifiers for Telecommunications 2*, M. N. Islam, ed., Vol. 90/2 of Springer Series in Optical Sciences (Springer-Verlag, NY, 2004), pp. 413–443.
- [9] G. P. Agrawal, “*Fiber-Optic Communication Systems*”, Wiley, NY, 2002, pp. 232–243.
- [10] Z. G. Lu, A. Lavigne, P. Lin, and C. P. Grover, “An erbium/ytterbium co-doped double-cladding fiber amplifier with 36.4-dBm output power,” *Proc. SPIE* 5577, 180 (2004).
- [11] Scott B. Kuntze, Baosen Zhang, Lacro Pavel, and J. Stewart Aitchison, “Impact of Feedback Delay on Closed-Loop Stability in Semiconductor Optical Amplifier Control Circuits”, *JOURNAL OF LIGHTWAVE TECHNOLOGY*, VOL. 27, NO. 9, MAY 1, 2009.
- [12] Hirotaka Ono, Yutaka Miyamoto, Takayuki Mizuno, Makoto Yamada, “Gain Control in Multi-Core Erbium-Doped Fiber Amplifier With Cladding and Core Hybrid Pumping”, *JOURNAL OF LIGHTWAVE TECHNOLOGY*, VOL. 37, NO. 13, JULY 1, 2019.
- [13] Sun Hyok Chang, Seung Kwan Kim, Hee Sang Chung, and Moo-Jung Chu “Transient Effects and Gain-Control Method in Low-Noise Dispersion-Compensating Hybrid Fiber Amplifier”, *IEEE PHOTONICS TECHNOLOGY LETTERS*, VOL. 15, NO. 7, JULY 2003.
- [14] Sun Hyok Chang, Hee Sang Chung, Hyun Jae Lee, and Kwangjoon Kim “Suppression of Transient Phenomena in Hybrid Raman/EDF Amplifier”, *IEEE PHOTONICS TECHNOLOGY LETTERS*, VOL. 17, NO. 5, MAY 2005.
- [15] Shien-Kuei Liaw, Yu-Sheng Huang, Hsin-Kai Hung, Nan-Kuang Chen, Kuei-Chu Hsu, Yi-Lin Yu1, Ting Wang1, A. Manshina and Y. Tver’yanovic “Dispersion Management and Gain Flattened for a Bridge-Type Hybrid Amplifiers in a Pumping Recycling Mechanism”, 2010 International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT).
- [16] Mamoru Hashimoto, Hisashi Sawada, Minoru Yoshida, Yoshiyuki Imada “A New Method for Low Noise Automatic Gain Control of EDFAs for WDM Systems in Metropolitan Networks”, *Proc. 27th Eur. Conf. on Opt. Comm. (ECOC’01 - Amsterdam)*.
- [17] Barbara Dumas, Sebastian Lara and Ricardo Olivares “Link Control Protection in Cascades of Optical Hybrid Amplifiers (EDFA + DFRA)”, 3rd Fiber Optics in Access Network- FOAN2012.



- [18] Hongxing Dai, Jin-Yi Pan, and Chinlon Lin, “All-Optical Gain Control of In-line Erbium-Doped Fiber Amplifiers for Hybrid Analog/Digital WDM Systems”, IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 9, NO. 6, JUNE 1997.
- [19] Changqing Huang, Xinyong Dong, Shuyuan Zhang, Nan Zhang and Perry Ping Shum “Cascaded Random Fiber Laser Based on Hybrid Brillouin-Erbium Fiber Gains”, IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 26, NO. 13, JULY 1, 2014
- [20] Hiroataka Ono and Makoto Shimizu “Analysis of Gain Dynamics of Erbium-Doped Fiber Amplifiers for Wavelength-Division-Multiplexing Networks”, IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 26, NO. 13, JULY 1, 2014



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